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STATISTICAL ANALYSIS OF PERSONNEL DATA
USING FACTOR SCORING, CLUSTER ANALYSIS,
AND MULTIDIMENSIONAL SCALING

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INTRODUCTION

This report is one of six Naval Postgraduate School technical reports documenting and describing a research project titled, "Design of an Operational Personnel Development and Evaluation System," sponsored by the Naval Material Command. The following is a listing of these six reports:

1. NPS-55Gh73061
DESIGN OF AN OPERATIONAL PERSONNEL
DEVELOPMENT AND EVALUATION SYSTEM
by: William H. Githens, Richard S. Elster,
Gerald L. Musgrave, and John W. Creighton.
2. NPS-55Ea73061
DESIGN OF OPERATIONAL CAREER LADDERS
by: Richard S. Elster, Robert R. Read,
William H. Githens, Gerald L. Musgrave,
and John W. Creighton.
3. NPS-55Gh73062
DESIGN OF AN OPERATIONAL MANAGEMENT
DEVELOPMENT MANUAL
by: William H. Githens, Richard S. Elster,
Gerald L. Musgrave, and John W. Creighton.
4. NPS-55Gh73063
DESIGN OF AN OPERATIONAL RATING MANUAL
by: William H. Githens, Richard S. Elster,
Gerald L. Musgrave, and John W. Creighton.
5. NPS-55Mf73061
DESIGN OF AN OPERATIONAL MANAGEMENT BY
OBJECTIVES MANUAL
by: Gerald L. Musgrave, Richard S. Elster,
John W. Creighton, and William H. Githens.
6. NPS-55Re73061
STATISTICAL ANALYSIS OF PERSONNEL DATA USING
FACTOR SCORING, CLUSTER ANALYSIS, AND MULTI-
DIMENSIONAL SCALING
by: Robert R. Read, Richard S. Elster,
Gerald L. Musgrave, John W. Creighton,
and William H. Githens.

An executive summary of the entire project follows, and any additional information about the project can be obtained from the Project's Principal Investigator, Dr. Gerald L. Musgrave, Department of Operations Research and Administrative Sciences, Naval Postgraduate School, Monterey, California 93940.

EXECUTIVE SUMMARY
OF
THE PERSONNEL DEVELOPMENT AND EVALUATION SYSTEM

INTRODUCTION

The purpose of this research project was to develop and implement a management system to more effectively utilize civilian professionals. Two "test bed" activities were selected--Naval Supply Center and Naval Regional Finance Center, both in San Diego, California. The project has four parts:

1. Establishing a Group Appraisal System.
2. Developing a Goal Setting System.
3. Constructing Performance Rating Scales.
4. Developing Career Ladders.

GROUP APPRAISAL

The management development program involved civilian professionals at the two commands in group performance appraisal sessions. A professional's work performance was usually appraised by his supervisor and by the supervisor's superior. This group would meet with a member of the research team. The appraisals conducted by these groups were focused on, and limited to, intra-appraisee considerations. That is, the appraisal committee considered the individual in terms of his greatest strengths and his least strong work performances, but did not compare the appraisee with other individuals. Recommendations for the appraisee, for the appraisee's supervisor, and for the organization were then made so that this appraisee (a "human asset") could grow in worth to himself and to the organization.

A summary of the appraisal committee's thinking was then written by the research team member who had attended the committee's meeting and given to the appraisee's supervisor for his review. The supervisor then discussed the appraisal with the appraisee, stating that this is "how others see and interpret you," and that "here are our thoughts on how you might further develop and utilize your talents."

The responses to the appraisal program were varied. A number of appraisees stated informally that they felt their appraisal session with their supervisor had been one of the most meaningful experiences they had while in the Civil Service. Many supervisors, however, experienced their first exposure to a face-to-face dialogue with one of their subordinates and found the feedback session to be somewhat traumatic. The development of supervisory skills in these feedback behaviors appears to be a crucial requirement if face-to-face dialogues between supervisors and subordinates are to become common and meaningful.

GOAL SETTING

Another part of the project was to establish a framework to foster and facilitate a "result oriented" management system. Our experience was that effective goals could be established and that while it took time to develop goals, the act of setting goals was beneficial to the organization.

Goal setting was new to managers and they were resistant to formalizing goals. Some of the resistance seemed to be attributable to unfamiliarity with the concept of producing results, as compared to being engaged in activities. Another resistive force seemed to be the fear that goal setting would be used for punitive managerial actions.

We believe that after more experience is gained in goal setting and when employees' fears of consequential management action are found to be unwarranted, a greater acceptance of the program will result.

Our research at the Naval Postgraduate School and the San Diego Centers leads to the development of a new Goals and Controls System. This system includes a Work Performance Folder and a Goal Setting Manual that is to be used in conjunction with the folder. The system can be used to formulate goals, monitor and control performance, and to appraise work performance at the end of the year.

PERFORMANCE RATING SCALES

Section IV of this report presents the rating scales which were developed for professional occupations in Supply and Finance.

ANCILLARY STUDIES

The project report includes a number of sections which are indirectly related to the central issues of performance appraisal, goal setting, scale construction and career ladders. These related sections include analyses of questionnaires administered to individuals at the Centers, bibliographic resource materials, and a number of related ancillary studies. These studies are related to human asset accounting, goal setting, auditing, and statistical analyses of organizational climate and attitudinal data from the Centers.

BACKGROUND

During Fiscal Year 1972, the Navy Material Command financed investigations by Naval Postgraduate School (NPS) faculty as part of their exploratory research directed at developing methods and means for improving organizational effectiveness. In the course of various dialogues concerning NAVMAT operations, topics related to the age and replacement of professional civilian personnel were discussed. These discussions then turned to the issues of performance evaluation and management by objectives. The Office of Civilian Manpower Management (OCMM) became interested in these problems, and the NPS was requested by NAVMAT and OCMM personnel to submit a proposal for implementing some relevant managerial programs during FY 73. NPS responded with the proposal included as Appendix 1 in NPS-55Gh73061.

The proposal involved the following main objectives:

1. Developing for each civilian professional specific ways in which he can improve his knowledge, skills, attitudes, or behaviors to make him a more valuable human asset for the Navy.
2. Develop for each civilian professional a list of specific ways in which management can better utilize his talent.
3. Advise each civilian professional of what his boss wants him to accomplish during the coming year, and the evidence that will be used to judge such accomplishment.
4. Generate for each professional position the best performance rating scales allowed by current technology.
5. Generate "career ladders" for civilian professional jobs that relate field jobs to jobs in Washington, D.C. These "ladders" were to be based on the similarities and differences between and among jobs.

The on-site locations for this "demonstration" project were the Naval Supply Center, San Diego, and the Navy Regional Finance Center, San Diego. The main administrative offices for both organizations are located in the same building and both organizations are served by the same personnel department. These two organizations were chosen because: (1) they are located in the same building, (2) this choice would allow one of the principal investigators to be on-site full-time, (3) they were within reasonable commuting distance from the Naval Postgraduate School in Monterey, and (4) both were considered by NAVMAT and NAVCOMPT personnel to be relatively healthy and efficient organizations.

A combination of "Management by Objectives" and "Group Appraisal" was used in accomplishing the first three of the five above objectives. Working from the higher toward the lower positions in the organizational hierarchy,

each supervisor called a committee meeting with his supervisor and several other employees who would have been in a position to observe the work performance of the appraisee. Following a brief discussion of the "strongest" and "least strong" aspects (intra-individual) of the appraisee's performance, the committee developed a list of recommendations in keeping with the first two of the aforementioned objectives. (Each of these discussions focused only on intra-individual differences.) Following this group meeting, the supervisor conducted a counseling session with the appraisee during which the opinions and recommendations of the committee were discussed. With this as a background, the supervisor and appraisee then worked out a list of specific goals for personal development to be accomplished during the coming year. In addition, based on the requirements and expectations of work accomplishment for the coming year as worked out by the supervisor and his boss, the supervisor and the appraisee (subordinate) worked out a list of goals for organizational accomplishment (objective #3) applying to the appraisee. Thirty of the 85 professional employees at NSC and all 25 of the professional employees at NRFC were covered by this program. Part II of this report deals with the developmental activities involved in objectives 1 and 2, while Part III of this report is concerned with the MBO portion (objective #3) of the project.

Generation of the best performance rating scales for each professional job (objective #4) involved the following scale construction steps:

1. A group of employees (3 to 6) familiar with the job listed the most relevant aspects of performance for the specific job.
2. The group then generated "specific" behavioral examples they had observed that demonstrated high and low performance on each performance aspect.
3. At a later time, these behavioral incidents were presented to the individuals in the group, who assigned them to the rating scale (aspect) and rating scale level (low to high on a 5-point scale) that they thought appropriate.
4. Incidents that were not by consensus assigned to the same location (both rating scale and level) were eliminated.

This procedure yielded rating scales that are relevant to the job being rated and that are "anchored" by specific behavioral incidents representing on the scales the various levels of job performance.

Rating scales were constructed for 6 of the 27 civilian professional jobs at NSC and for 3 of the 7 jobs at NRFC. General "supervisory" scales were constructed covering 11 of the 21 remaining jobs at NSC and all 4 of the remaining professional jobs at NRFC. Part IV of this report and Technical Report NPS55Gh73063 present the scale construction work conducted during the research project.

In support of objective #5, a task inventory asking employees to list the degree to which they were involved in various activities was administered

to 85 civilian professionals at NSC and 26 civilian professionals at NRFC. The same inventory was completed by civilian professionals in NAVSUP and NAVCOMPT in Washington, D.C. The data from the responses to this inventory formed the basis for the investigation of career paths, which was objective #5 of this project. The research done on career paths is described in Technical Report NPS55Ea73062.

Another technical report in this series, NPS55Rr73061, contains ancillary studies conducted during the term of this project. These studies included one using multidimensional scaling in examining how supervisors differentiate among their subordinates, and another effort which involved developing a comprehensive bibliography of the Management by Objectives literature.

MULTIDIMENSIONAL SCALING OF PERSONNEL PERCEPTIONS

One of the objectives of the NSC/NRFC project was to investigate means for the selection of personnel who might be educated or trained for advancement. One of the criteria for such a selection is the ability of the person to get along with other people. This quality involves the respect of others and the ability of the person to fulfill the requirements that others perceive to be important in a job.

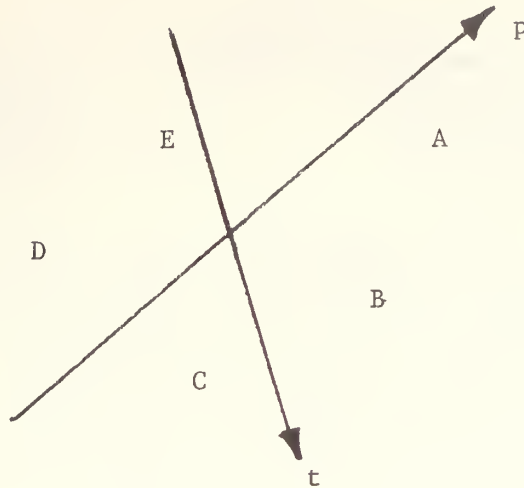
Such a quality is difficult to measure, for it depends upon the opinions of people who can be expected to be reluctant to state whether or not a person's characteristics are good or bad and why they are good or bad. Since a direct measurement approach is difficult, the study team decided to use a system which would give such a measure without asking any direct questions of personnel in the organization. This technique is called multidimensional scaling. In this system, the subjects need only to identify how similar or dissimilar they perceive their colleagues as being to one another. These comparisons are usually made by having the respondent consider one pair of subjects at a time.

A simple example will help to illustrate the technique. Consider five personnel designated A, B, C, D, and E, and suppose each is asked to state, on a psychological scale of 0 to 9, how far apart from one another they perceive the employees in each pair as being. Thus, one person might perceive A and B to be very similar and scale that pair as "one", whereas A and C may be perceived as being very dissimilar and hence scaled at "eight", etc. These scalings can be averaged over the individuals who respond in order to produce a half matrix such as the following:

A	0				
B	2.5	0			
C	5.0	3.0	0		
D	5.5	4.5	2.5	0	
E	3.5	3.5	3.5	2.5	0
A	B	C	D	E	

Note that no individual is asked to state which member of a pair is "better", nor is he identified with his response (anonymous responses). The above half matrix of averages, therefore, represents an average of the group's perception.

Data of this type resemble a mileage table that often appears on road maps. In fact, one can view the data as such and try to reconstruct positions of the cities on the map. Thus, using the fictitious data from above, points A, B, and C must lie on a circle of radius 3.5 from E. Points A and C must be 5 units apart while B is about 2.5 units from A, and all three of these are on the originally constructed circle. Proceeding in this fashion leads to the following comparative locations for the points:



Hence, the goal of achieving a spatial representation (locating the cities) of the five personnel has been achieved. In this example, the ten entries in the data set were contrived so that the two-dimensional construction process could be completed without any substantial inconsistencies. Unfortunately, such tidy solutions do not too often happen with this kind of data and more than two dimensions may be needed to represent the points geometrically.

Having achieved the above representation, how does one interpret it? First, it would show that there are two main dimensions underlying the group's perception of their colleagues. What remains is the interpretation of these two dimensions. Suppose it is learned that the group's supervisor considers A to be a person of high productivity, C and D are of low productivity, while B and E are moderate producers. Then, one would feel justified in constructing a scale and labeling it "p" for productivity as has been done in the previous diagram. Suppose further that it is learned that C is a very thorough individual, E is sloppy and careless, while A, D, and B are rated as being moderately thorough. Then one would feel justified in constructing and labeling the "t"-scale (for thoroughness) as was done on the diagram. Thus, the goal of this multidimensional scaling technique is to discover and represent the dimensions of perceptions.

In this example, two things have been exposed that may not have been otherwise learned. First, the group perceives productivity and thoroughness as the important dimensions separating the personnel in that group. Second, the perceived positions of individuals on these dimensions have been learned.

It was decided to try this multidimensional scaling technique with some San Diego Supply personnel in order to demonstrate its possible usefulness. Discussion with Supply personnel in San Diego led to the selection of the following five groups for this pilot study:

Code 3051:	Screen I.D. and Special Projects	(7 people)
Code 1011:	Inventory Management	(8 people)
Code 5311:	NSF/Reconciliation	(7 people)
Code 5232:	Allotment Sec. III	(7 people)
Code 5332:	Payroll and EAM	(8 people)

There was prepared for each group (code) a lower triangular matrix with the names of the employees heading the rows and columns, analogous to a mileage table on a map in which the rows and columns are headed by cities and entries in the matrix represent distances between the cities. In fact, this analogy was used to instruct the respondents. Instead of distances between cities they were requested to enter distances between pairs of fellow workers. These distances were to be on a psychological scale of 0 to 9 and in terms of "value to the organization". Several asked for a more explicit breakdown as to what this meant, and it was explained that such determinations were to be made by the respondents. Indeed, the purpose of this exercise is to determine the number and character of the important dimensions perceived by the group in common.

This latter point seemed difficult to get across. Many respondents, upon learning that zero meant that no difference in the two individuals' values to the organization could be perceived by them, proceeded to enter all zeros. Others were concerned about how to designate which member of the pair was better. The reply was that it was not necessary to so state, but only necessary to indicate how far apart they were. It appeared to the researchers that not all of the respondents were comfortable with this answer. Finally, it was necessary to instruct codes 5311, 5323, and 5332 all at once and in a room where no one could sit down. This fact contributed to a lack of communication and cooperation.

The data were collected, processed, and received with each code's supervisor. The results of each review follow immediately. After these, a summary is presented.

CODE 5323

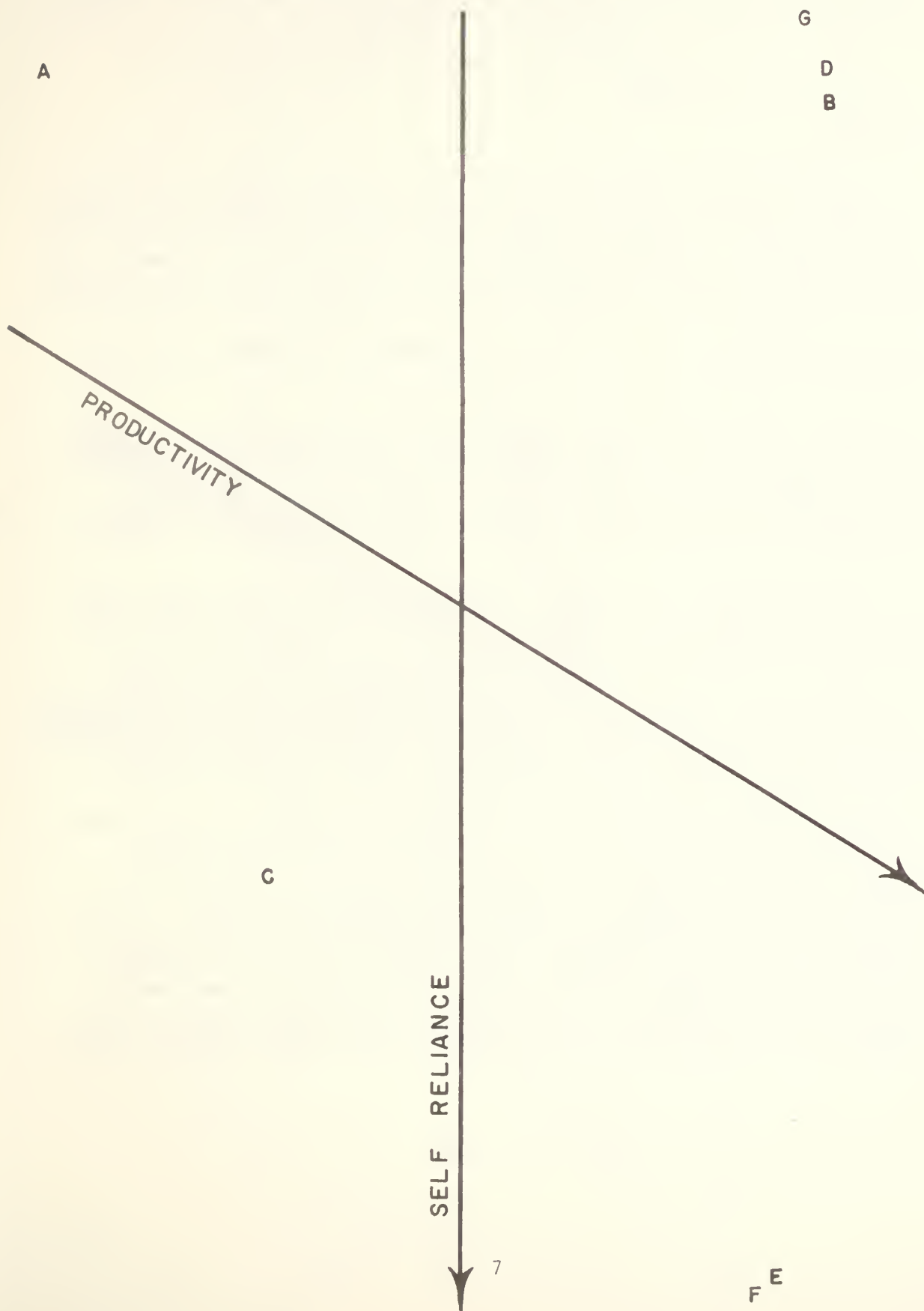
Code 5323 has seven women and a woman supervisor. One was absent on the day of the data collection, and the remaining six responded. A two-dimensional solution was found satisfactory and was readily interpreted by the supervisor. The representation of the solution and the dimensions are presented in Figure 1.

The supervisor's interpretation follows:

E and F are people of high productivity, initiative, and seem to know how to handle their problems.

A is an individual of low productivity, who gripes, and wants tangible rewards for doing something extra.

FIGURE 1
CODE 5323



D and B do very average work, have similar personalities and are somewhat indecisive. G is new and hence unknown to the group. C is a physically handicapped person who is doing the best she can. She is not very mobile (e.g. can't leave her desk to reach the filing cabinet) and this is seen as influencing her productivity.

Thus, the two dimensions appear to be Productivity and what we shall call Self Reliance.

CODE 3051

Code 5031 has seven men (A through G) and is supervised by a man. All seven supplied data, but some of the forms were incomplete. It was necessary to go to three dimensions to get a satisfactory solution. The diagram (Figure 2) exhibits a string of four people: F, G, B, and C, with a fifth, D, along the same line, but D is much lower in the vertical plane. This grouping is flanked by A on one side and E on the other.

A discussion with the supervisor yielded the following interpretations:

F is a new man (he had been with the organization about a year and a half). He is quiet, plugs along, and not very knowledgeable about marine applications of the equipment. He came here as the result of a RIF (elsewhere) and would not, under ordinary circumstances, have been selected for his position because of the investment in training involved.

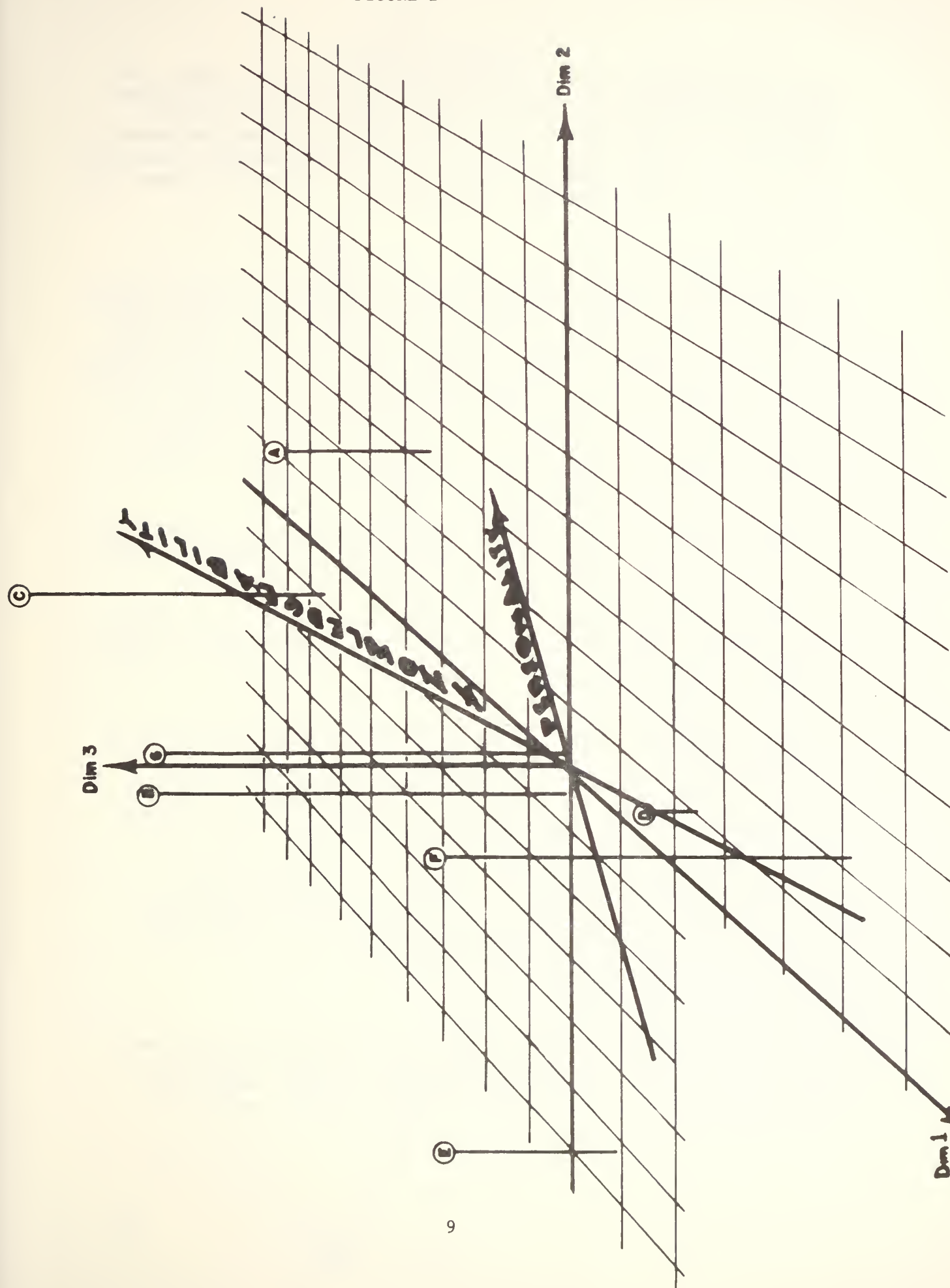
C is the most knowledgeable man in the section. He is ambitious, wants a promotion, likes to do new and different things, and has a tendency to socialize (swap stories with others). C and F are the only two in the section who are not close to eligibility for retirement.

B and G are quite similar and close to the middle in terms of value to the organization. D is very steady. He doesn't like new jobs or to make decisions. He is a loner (non-social) and "moans and groans".

A and E are the top "doers" of the section. They both are go-getters who show lots of initiative and frequently draw special jobs.

It was very surprising to find that A and E are perceived by the group as being so different, so the point was pursued further. A is rough cut and a leader ("Let's get off our tails and get the job done") whereas E is more of a diplomat. Also, many of E's work assignments take him out doors away from the gang. A has lunch with the "core" (C, D, B, and G), whereas E eats alone. The supervisor suspected that this lack of group contact is the dimension that splits E from A in the perception of the group.

FIGURE 2



It was difficult to label the third dimension of these data. The main theme appeared to be knowledgeability, while the A to E direction suggested a personality or perhaps leadership/popularity dimension. The withdrawn conservative is low in the vertical, whereas the gregarious types seem rather high. The fact that the representation cannot be more sharply described suggests that there may be perceptual ingredients present of which the supervisor is not aware.

CODE 5332

Code 5332 has eight people, two of which are males (A and H), and a female supervisor. One person was absent on the day of the data collection, and five of the remaining seven turned in data sheets containing all zeros. Thus, either they were unable to differentiate among their fellow section members, or they were unwilling to share any such perceptions with the researcher. Also, there were many zeros on the two data sheets that did contain information. It was decided to complete the analysis even though the data are a very small sample.

A two-dimensional solution was found to be satisfactory and the results were readily interpreted by the supervisor.

Individuals F, G, and H are retirement clerks. The others are payroll clerks and the two subgroups have virtually no professional interaction. The two subgroups are clearly separated in Figure 3.

F, the head retirement clerk, has overall responsibility, is very exacting and does everything "by the book". H resents this, has sloppy work habits, and frequently is made to do things over again. G is in between, and just goes along.

Turning to the other subgroup: B is slow, thorough, and very accurate in her own way, but it is not possible to get her to do things the way others do them. C and E are quite similar to one another, also, they are the oldest and are felt to resist change. A and D are both high on initiative and volunteer for extra work. D is a trainee while A (a male) has performed work similar to this for many years.

Thus, the plot really has two parts, one for the retirement group -- which is essentially one dimensional and represents sharp attention to detail. The other plot is for the payroll group which has two dimensions -- one for experience, and one for a combination of what we shall call Speed and Conventionality.

CODE 5311

Code 5311 has seven people, two of which are male (A and F), and a female supervisor. One was absent the day of our data collection, and three turned in data consisting entirely of zeros. Again, the analysis was conducted even though the sample was very small.

FIGURE 3

CODE 5332

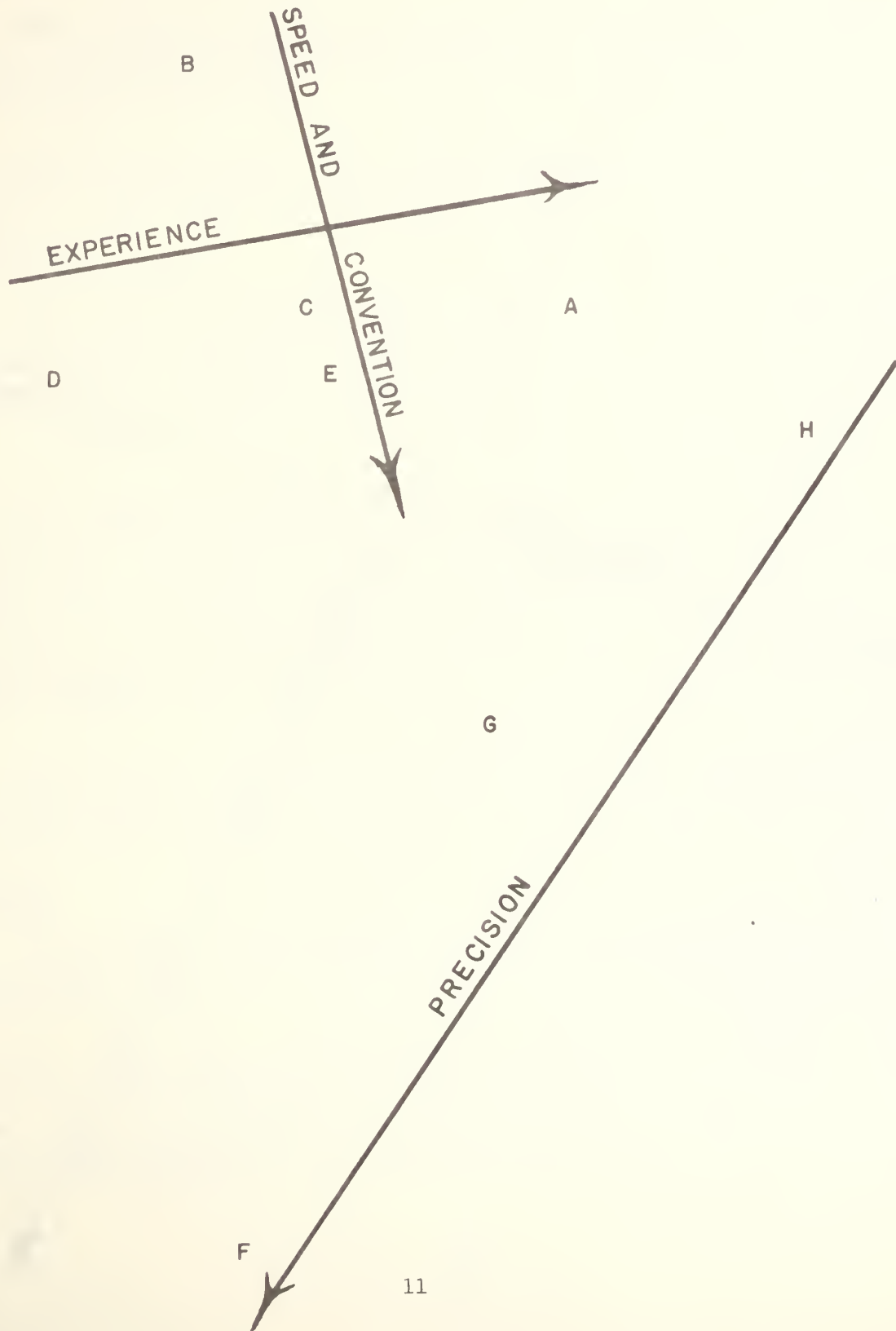


FIGURE 4

CODE 5311



F is a most aggressive individual who will not rest until he solves a problem -- he "digs". D was trained by F and is also a "research type". G is a very demanding and stubborn person who is low on initiative and bypasses the organizational structure when she has a complaint. A is a quiet, non-demanding, non-aggressive individual who works steadily and gets nervous if pushed.

The supervisor would rate B and C about the same. C has been longer on her job and her output should be greater, so perhaps the group has picked up on that situation. E has an "OK" personality and also has not been on the job as long as C.

Thus, the two dimensions in Figure 4 appear to be initiative and some sort of intenseness or energy expenditure dimension. The supervisor may wish to look farther in interpreting the separation of B and C.

CODE 1011

Code 1011 has seven women and one man, H. The supervisor is a woman. One was absent on the day of the data collection and only three of the remaining seven supplied discriminating information. Even so, three dimensions were necessary to obtain a satisfactory representation.

Obviously, the man, H, is sharply separated from the rest.

The supervisor felt that the separation of B and D was astounding. D is the youngest and probably one of the best. Some feel that D gets preferential treatment. B is very conscientious and does rather different work. E, F, and G have been on the job a long time (about 25 years or so). E has the best overall knowledge, but has personality problems (does not get along well and can't communicate). F is very outgoing. C is friendly, outgoing, and does a good job. A is withdrawn, keeps to herself, and does not have broad experience. H is also withdrawn.

The supervisor felt that the separations exhibited (see Figure 5) are rather special. She sees clustering by personalities, car pools, and who lunches with whom. No attempt was made to interpret the dimensions found for the data from this code.

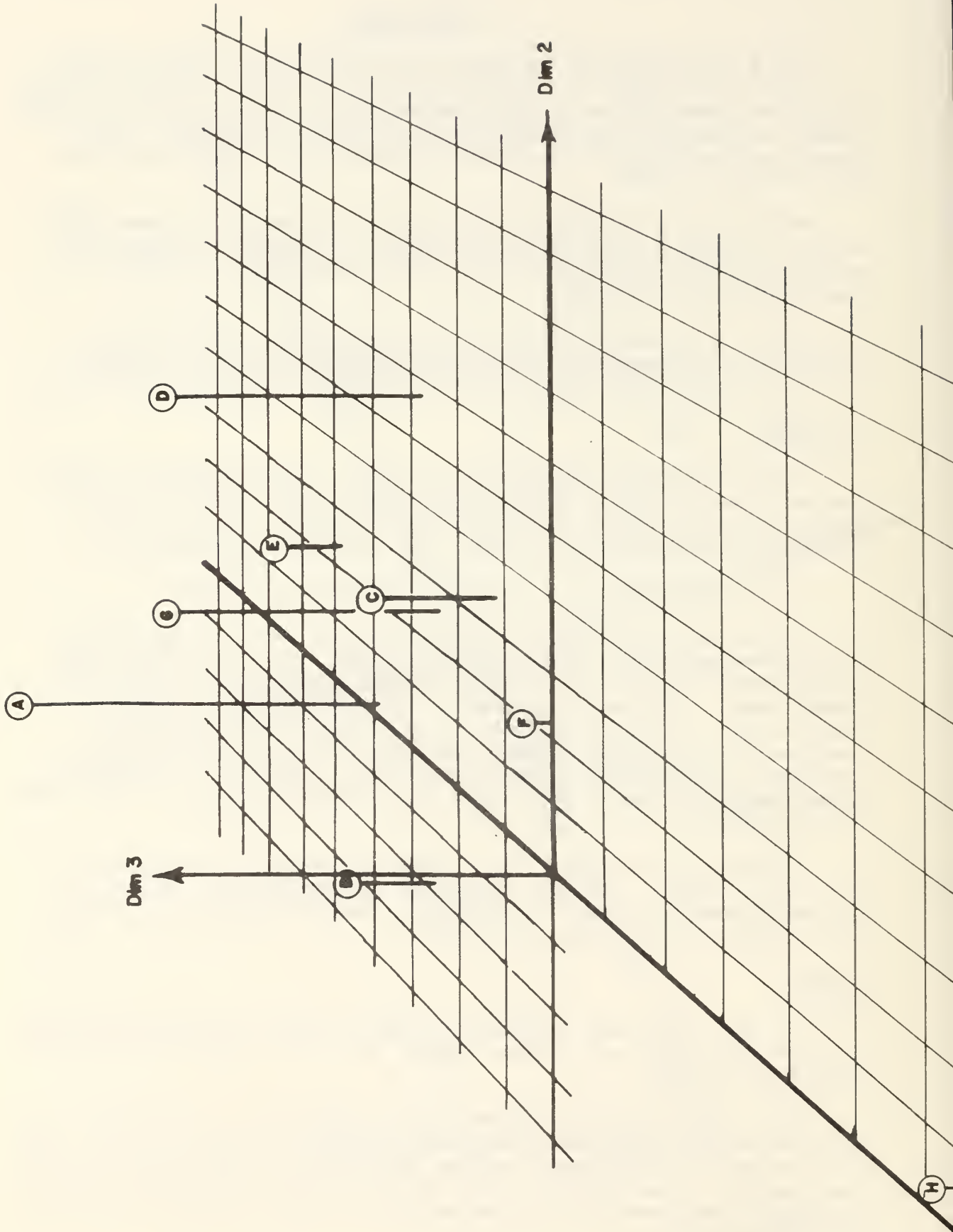
SUMMARY

Code 5323 had a good response rate and an easily interpreted solution. This suggests that there is good rapport between the supervisor and the people in the code.

Codes 1011, 5311, and 5332 had a poor response rate. This may be attributed to poor instruction, poor understanding, or poor attitude. Even so, the results of 5311 and 5332 were interpretable, although the results were based on a few responses. The results from 1011 seem useful only in telling us that those who did respond may have views different from those of the supervisor.

FIGURE 5

CODE 1011



Code 3051 provided a good response rate, but only two of the three dimensions were interpretable by the supervisor. Thus, he is alerted to the possibility that an ingredient of rapport may be missing between him and his people. Also, he was surprised to learn that his two best "doers" were split apart in the perceptions of the group.

USE OF FACTOR SCORING AND CLUSTER ANALYSIS

WITH DATA FROM THE OCMM SURVEY

In addition to the application of multidimensional scaling, cluster analysis and factor scoring techniques were applied to personnel data collected at the Naval Supply Center, San Diego. The Navy Office of Civilian Manpower Management (OCMM) developed the Civilian Personnel Management Survey as an instrument to aid in the self-evaluation of various Navy shore activities. The questionnaire focused on civilian personnel management programs. Each civilian in the command is asked to respond to sixty-five statements about the actual operation of the organization. A list of questions is presented in Table 6. The response choices are to agree, disagree or be undecided about the statements. Two forms are used, "supervisors" and "employees," and responses are made on separate optically scanned answer sheets. The results of the responses are centrally tabulated and returned to the activity. An example of one tabulation is presented in Table 2.

To aid the activity, the sixty-five questions are categorized into eleven "program areas" which are used to identify a variety of personnel management programs. These eleven areas are Merit Promotion, Training, Labor-Management Relations, E.E.O., Classification and Pay, Position Management, Job Information and Performance Evaluation, Communication, Supervision, Employee Services, and Morale. In addition to the raw scores, the command's responses are compared to the Navy average.

The scoring system operates as follows. For each question, a determination is made as to whether an "agree" or "disagree" response is supportive (indicative of satisfaction) with the present operation of the activity. Scores (percentage responses) on the so-designated answers are compared with Navy average responses on a question-by-question basis. For each program area, the total percentage differences over all questions is divided by the number of questions in that program area. From these data it is determined how the activity compares with the Navy average for each program area. An example of this summary is provided in Table 1. OCMM feels that there are no right or wrong answers. The results are to be used to identify those areas where there is a high degree of acceptance and support, and areas which may be in need of better communication, redirection, or other management action.

Further insight into the details, philosophy, development, and progress of this survey can be obtained from the following four articles:

1. Masse, S., "Evaluation--A New Generation Concept," Civilian Manpower Management, Vol. III, No. 2, Summer 1969, pp. 22-24.

2. Berne, E., "Evaluation--A New Generation Concept Progress Report I," Civilian Manpower Management, Vol. IV, No. 3, Spring 1970, pp. 27-30.

3. Froscher, C.T., Capt. USN, "Evaluation--A New Generation Concept Progress Report II," Civilian Manpower Management, Vol. IV., No. 2, Summer 1970, pp. 20-29.

4. Masse, S., "The Questionnaire Survey Technique," Civilian Manpower Management, Vol. IX, No. 3, Fall 1971, pp. 6-11.

It would seem reasonable to believe that the presentation of the OCMM survey data could be simplified to a substantial extent. That is, the manager who uses the results might be able to glean the information garnered by the survey without having to examine the responses to all the items in an area or in the survey. The techniques of cluster analysis are exploitable for this purpose. Indeed, Masse* has pointed out that "Numerically significant clusters of responses should clearly point up areas for further investigation." Also, when administrative action is taken in an area, the perception of the affected personnel could change not only there but in other areas as well. Thus, action should be directed toward all the personnel who have common perceptions, if possible. The purpose of this study is to illustrate just how such clusters of personnel (responses) can be identified.

More specifically, the use of cluster analysis in a pilot study (1972 OCMM survey for NAVSUP, San Diego) has led to the identification of six clusters of personnel. Each cluster is scored on each program area (see Figure 1) and those clusters contributing to unusual performances exhibited in Table 1 are identified. Such identification occurs only through the associated personnel profiles since the original responses are anonymous. As a result of the pilot study, the following items have been brought out:

1. The high performance in Labor Management Relations is due to the combined perceptions of clusters C2 and C5. This same pair causes above average ratings in Position Management. These two clusters have more than their share of twenty-year people (see Table 5).

*Journal of Navy Civilian Manpower Management, Vol. III, No. 2, Summer 1969.

2. The above average rating in Communication is due to the perceptions of clusters C1, C4, and C6. No military personnel are identified with these three clusters, and C1 and C4 have a sharply disproportionately high number of females. Curiously, C2 and C5 perceive communication to be relatively poor.

3. The two pairs, C1-C4 and C2-C5, behave as two single clusters for most program areas. The most singular exception is their scores on Equal Employment Opportunity. There, C1 and C5 pair up (with C6) to drive the above average rating while C2 and C4 detract from it. This particular area is governed virtually entirely by the response to Item 19 - "minority members perform as well as others". One might expect that these clusters would have a disproportionate number of minority personnel, but the numbers are not significant (see Table 5). There is a moderate tendency to associate higher education with C5.

Deeper probing is possible and is illustrated later on. The technique is presented first. The following paragraphs provide an overview of the data reduction steps that could be used to locate clusters. After that, these steps are applied to the CY 1972 responses with broad-based normative data, hence the illustrative results are limited to an internal (NAVSUP) comparison.

The objective of the data analysis method is to group the respondents into clusters of individuals who gave similar responses to the questionnaire. Obviously, if we required all members of a given cluster to have exactly the same responses on all 65 items in the OCMM survey, then one would have a very large number of clusters, and no particular advantage would have been gained from the clustering. One desires a handful of clusters such that within a cluster the responses of the individuals in the cluster are very similar, and yet there are substantial differences among the responses of individuals in different clusters. Computational routines* are available for forming clusters, but generally these methods are not computationally feasible if the number of items is larger than 20. This problem can be circumvented by first grouping the 65 items into a set of "factors" so that the number of such factors is under 20. Each respondent must then be assigned a score on each factor. One can help compensate for information lost in this preliminary grouping by choosing a scoring system that best captures the differences among the respondents' answers to the OCMM survey. The technique chosen involves the items' being weighted in such a way that the variability among the responses to the survey is maximized.

The clustering procedure is applied to the correlations among the scores received by the respondents on the factors that were developed. Objective criteria are available for determining the number of clusters having substantial inter-cluster separation and minimal intra-cluster

*McRae, D.J., Clustering Multivariate Observations, Ph.D. Thesis, Univ. of N. Carolina, 1973.

separations. The individuals in any one particular cluster are those who gave quite similar responses to the OCMM survey. Having developed the clusters, one then tries to describe the clusters in terms of what responses the people in them had in common.

An Example:

For illustrative purposes, the procedures outlined above were used to examine the CY 1972 responses of 106 supervisory personnel at NSC, San Diego, to the OCMM survey. The procedural details chosen were somewhat ad hoc, but quite reasonable.

1. It was both convenient and expedient to use the eleven program areas (see Table 1) to serve as the factors. The items associated with each program area appear in Table 3. Such a choice represents the way that OCMM feels its survey is organized, although they make no claim that it results in sharp item groupings. Thus, further study of the groupings might be helpful.

2. Scores for each factor were formed by using the item weights that appear in Table 2. The scoring method used chose the item weights so that the variances of the factor (program area) scores were maximized. In this way, the discrimination among the clusters should have been made large. The item responses were converted to numbers by assigning 0 for "yes", 1 for "?", and 2 for "no". Missing responses were converted to "?" (or 1). Each numerical response was multiplied by the weight for that item, and program area scores were computed by adding these products over all items in the area.

3. A six cluster solution was chosen since it produced a noticeable break in the within group sum of squares, and Mahalanobis distance was used (see McRae, op. cit.). The number of personnel in each cluster is given by:

Cluster Number	1	2	3	4	5	6	Total
Number of People in Cluster	12	28	10	15	35	6	106

A visual display of the mean value of each factor for each cluster is given in Figure 1.

4. Normative data for this example are limited to the overall means for each factor. The scoring interpretations that appear in Table 4 provide tentative interpretations of the program area scores. Based on Table 4, the clusters are interpreted in the following several paragraphs.

It can be seen in Figure 1 that areas 7 and 11 (Job Information and Performance Evaluation, and Morale) provide minimal discrimination among the clusters. Note further that the two largest clusters, C2 and C5,

which account for 63 of the 106 supervisors, have similar centroids on all factors except area 4, EEO. In Table 3, it can be seen that this area relates highly to Item 19 ("Minority members perform as well as others"). It follows that cluster C5 consists largely of those supervisors who agree with the statement that minority members perform as well as others, and that cluster C2 contains those that disagree with it. On the basis of these data, one cannot state whether this difference is one of perception or of fact, but having called attention to the issue, one can decide if further investigation is needed. Also note that the people in both clusters C2 and C5 feel communication is poor.

The smallest cluster, C6, is a sharp outlier, having extreme positions on areas 1, 2, 6, 8, and 9. The people in C6 seem dissatisfied with the merit promotion program and not too happy with training, have few or no complaints about minority workers, feel communication is good, but feel their authority is lacking, and their high score on area 9 suggests dissatisfaction with their supervisory situation.

Clusters C1 and C4 are very close to each other on areas 1, 2, 3, 5, 6, 8, and 9, but separate on area 4 (EEO). Thus, the people in these clusters have some complaints about the merit promotion program, training, are somewhat anti-union, do not feel that employees leaving for higher pay is a problem, but feel they need more authority, and have some dissatisfaction with supervision.

The remaining cluster, C3, has 10 members and seems to have an intermediate position on all areas, except possibly morale (area 11), an area in which their attitude appears a bit negative. It is curious that this group has a conspicuously neutral position on area 4, EEO.

Having characterized the clusters, one is in a position to make in-depth studies of the extreme positions of clusters on areas. Thus, one might want to break down the item responses of C2 on all items in area 4 (EEO). The responses of C6 on area 1 (Merit Promotion) and area 8 (Supervisory) seem to be extreme and worthy of special attention, and so on.

5. To learn more about the clusters, one can summarize the demographic (profile) and other data available concerning people in the clusters. Some salient frequency counts appear in Table 5. For instance, from Table 5 we see that C1 and C4 have sharply disproportionate numbers of females, while the other differences between the people in the two clusters appear to be rather minor. C2 and C5 have an excessive number of 20-year people.

Cross-classification also can be made for purposes of typing or understanding the clusters. For example, cross-classifying education with work area for C5 yields the following table:

	<u>Scien & Eng</u>	<u>Other Prof.</u>	<u>Admin</u>	<u>Technical</u>	<u>Clerical</u>	<u>Trade</u>	<u>Total</u>
High School	0	1	1	2	2	6	12
College	0	3	1	2	0	0	6
Postgraduate	0	0	3	0	0	0	<u>3</u> 21

Thus, all those that have postgraduate training are administrators, all supervisors in the clerical or trade groups have a high school education, etc. It is possible that such comparisons could help in understanding the differences among the responses given by people in different clusters.

In summary, it is hoped that this example illustrates the kinds of analyses that are possible through cluster analysis. One can define clusters from the responses themselves, and can discover important differences in perceptions and attitudes -- helping to identify the human and organizational variables associated with such differences.

— Denotes Overall Mean

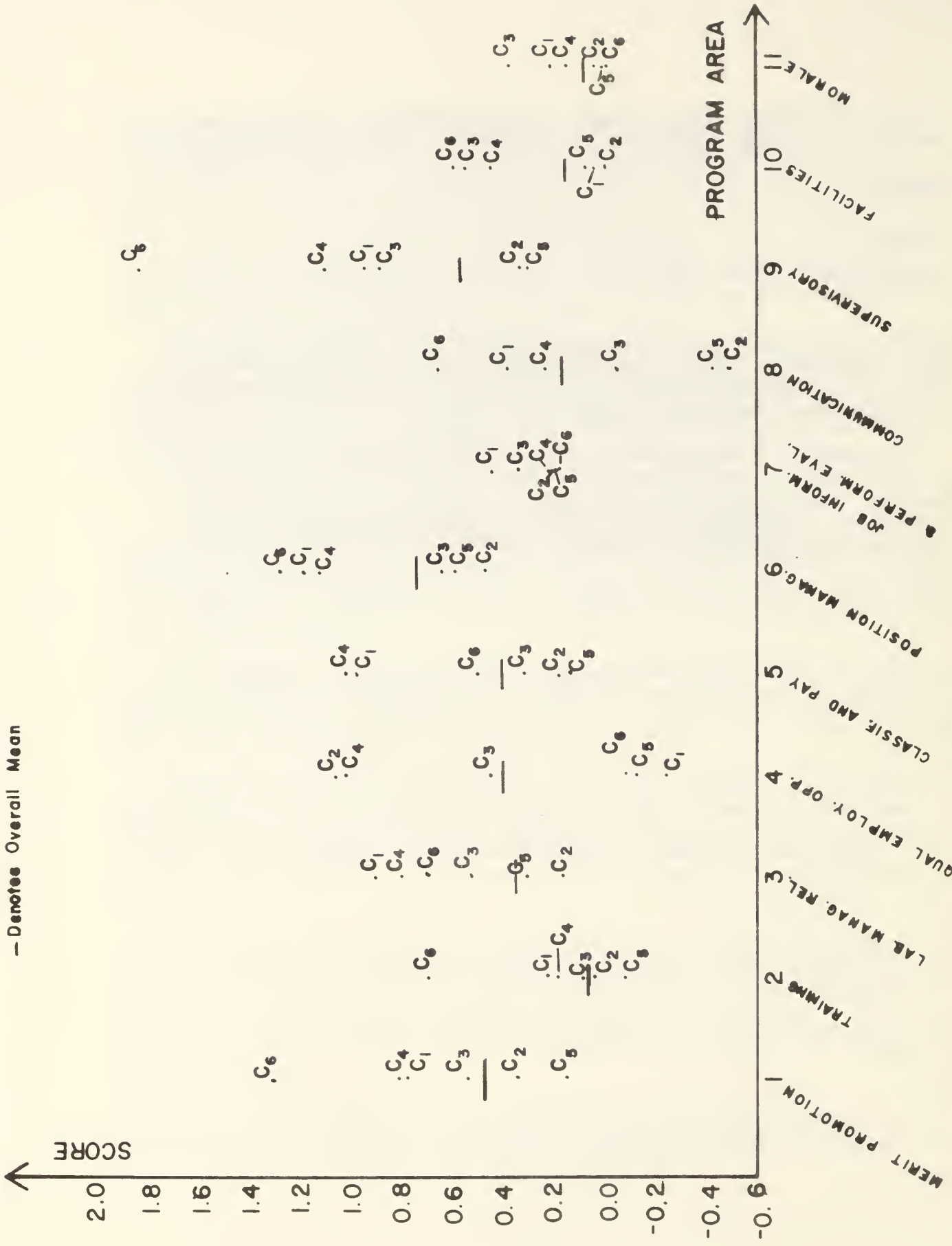


Figure 1

CLUSTER MEANS FOR EACH PROGRAM AREA

T A B L E 1

QUESTIONNAIRE RESULTS

NAVSUP San Diego, May 1972

Comparisons with Navy Average

E: Employees

S: Supervisors

Program Area	Sharply Above (10% or more)	Above (5% to 9%)	About The Same (Under 5%)	Below (5% to 9%)	Sharply Below (10% or more)
Merit Promotion	E ○ S ○	E ○ S ○	E ● S ●	E ○ S ○	E ○ S ○
Training	E ○ S ○	E ○ S ○	E ● S ●	E ○ S ○	E ○ S ○
Labor-Mgt. Relations	E ○ S ●	E ○ S ○	E ● S ○	E ○ S ○	E ○ S ○
EEO	E ○ S ○	E ○ S ●	E ● S ○	E ○ S ○	E ○ S ○
Classification & Pay	E ○ S ○	E ○ S ○	E ● S ●	E ○ S ○	E ○ S ○
Position Management	E ○ S ○	E ○ S ●	E ● S ○	E ○ S ○	E ○ S ○
Job Info/Performance Evaluation	E ○ S ○	E ○ S ●	E ● S ○	E ○ S ○	E ○ S ○
Communication	E ○ S ○	E ○ S ●	E ● S ○	E ○ S ○	E ○ S ○
Supervision	E ○ S ○	E ○ S ○	E ● S ●	E ○ S ○	E ○ S ○
Employee Services	E ○ S ○	E ○ S ○	E ● S ●	E ○ S ○	E ○ S ○
Morale	E ○ S ○	E ○ S ●	E ● S ○	E ○ S ○	E ○ S ○

01 (SUPV) I AM SATISFIED WITH THE QUALITY OF PEOPLE REFERRED TO ME FOR FILLING VACANT POSITIONS

	(SUPV)										TOTALS						
	CLASS ACT						WAGE BOARD				MILITARY		NUMBER	PER CENT			
	MALE		FEMALE		MALE		FEMALE		YES	?	NO	YES		?	NO		
	YES	NO	YES	NO	YES	NO	YES	NO									
TOTAL RESPONSES	15	7	7	14	3	4	13	2	12	1	1	42	12	25	53.1	15.1	31.6
EDUCATION																	
High School	12	4	6	12	2	3	12	2	11	1		36	8	21	55.3	12.3	32.3
College	3	2	1	2	1	1			1			5	3	3	45.4	27.2	27.2
Post Graduate											1			1		100.0	
FEDERAL SERVICE																	
00-03 yrs	1	2										1	2		33.3	66.6	
04-10 yrs	1											1			100.0		
11-20 yrs	2		1	3	1	3	4		1	1		9	1	7	52.9	5.8	41.1
Over 20 yrs	11	5	6	11	2	1	9	2	11			31	9	18	53.4	15.5	31.0
GRADE RANGE																	
GS 03-05, Leader	1			1	1	2	3		1	1		5	1	4	50.0	10.0	40.0
GS 06-09, Foreman	7	4	3	11	2	1	8	1	10			26	7	14	55.3	14.8	29.7
GS 10-13, Gen Foreman	7	3	4	2		1	1		1			10	3	6	52.6	15.7	31.5
GS 14-UP, Superinten									1					1	100.0		
GENERAL WORK AREA																	
Sci, Engineering Prof	1											1			100.0		
Other prof	2	1		4	1	1		1	1		1	6	3	3	50.0	25.0	25.0
Administrative	7	2	4	1				1	1			8	3	5	50.0	18.7	31.2
Technician	2	1	3	1		1	1			1		4	1	4	44.4	11.1	44.4
Clerical	1			7	2	2				1		8	2	3	61.5	15.3	23.0
Trade	1	2					9		9			10	2	9	47.6	9.5	42.8
LAST PROMOTED																	
Never	1				1							2			100.0		
0-5 years ago	11	5	2	10		4	5	2	5	1	1	26	7	13	56.5	15.2	28.2
More than 5 years ago	3	1	5	3	2		7		7			13	3	12	46.4	10.7	42.8
LAST TRAINING RECEIVED																	
Never					1	1						1	1			50.0	50.0
0-2 years ago	14	7	6	13	2	2	11	2	12	1	1	38	11	22	53.5	15.4	30.9
3-5 years ago			1			1								2		100.0	
More than 5				1			2					3			100.0		
MEMBER RACIAL MINORITY	1				1		2		1			3	1	1	60.0	20.0	20.0

T A B L E 2
TYPICAL PROFILE DATA SUMMARY

TABLE 3

PROGRAM AREAS OF SUPERVISOR RESPONSE ITEMS AND CORRESPONDING SCORING WEIGHT

<u>Item No.</u>	<u>Weight</u>
1. MERIT PROMOTION	
1) Satisfied with people referred	.16
11) Good applicants to choose from	-.13
18) Candidates in reasonable time	.41
25) Trained in supervisory appraisals	.38
2. TRAINING	
2) Job-related and pays off	-.16
6) Can get for employees in reasonable time	.30
32) Difficult to spare employees for (off-job)	.36
3. LABOR-MANAGEMENT RELATIONS	
9) Personnel Office assistance in dealing with unions	.10
35) Kept informed of provisions of agreements	.38
44) Feel free to treat union members/nonmembers the same	.37
54) Satisfactory dealings with unions	-.03
4. EQUAL EMPLOYMENT OPPORTUNITY	
7) Supported by top management and supervisors	-.06
16) Men and women have same job opportunities	-.01
19) Minority members perform as well as others	.59
31) Would mind working for a minority supervisor	.05
40) Minority members treated fairly	-.08
5. CLASSIFICATION AND PAY	
13) Known procedure when PD is out of date	.03
17) Participate in annual review of subordinates' PDs	.10
21) PDs limit my flexibility in assigning work	.14
26) Know when subordinates' PDs aren't current	.10
30) Employees leaving for higher pay is a problem	.54
37) Complete set of PDs available to me	.15
39) Difference in pay over subordinates' is adequate	.04
46) Pay is enough to attract qualified people	-.15
49) My PD describes what I do	-.08

<u>Item No.</u>		<u>Weight</u>
6.	POSITION MANAGEMENT	
3)	Certain functions should be combined	.32
28)	Received training in PM	-.13
43)	Some positions in my unit should do higher priority work	.14
45)	Aware of PM objectives	.02
50)	Could reorganize my unit to be more effective/efficient	.10
51)	Enough authority to reassign my employees	.41
56)	Getting maximum utilization of employees	.15
57)	My skills and abilities are well used	-.04
7.	JOB INFORMATION AND PERFORMANCE EVALUATION	
10)	Have some unsatisfactory employees	.01
12)	Periodically discuss performance with subordinates	.39
41)	I see that subordinates know job requirements	
62)	Boss lets me know when I do a good job	-.01
64)	Know what is expected of me	-.05
8.	COMMUNICATION	
5)	Given "why" on info to me, to answer employee questions	-.26
22)	My opinions are considered by management	.20
24)	Usually get info from grapevine first	.28
33)	Regularly attend supervisory staff meetings	-.09
38)	Rules and regulations available in writing	.10
42)	Have opportunity to help plan personnel policy	-.15
47)	Get most info at the same time as employees	.26
52)	Discuss changes with employees in advance	.02
9.	SUPERVISION	
4)	Used incentive awards system in past year	.11
8)	Not aware of any complaints or dissatisfactions in my group not properly dealt with	.19
14)	Have delegated authority appropriately	-.04
15)	Personnel people have more say about my employees than I do	.04
20)	Easier to transfer unsatisfactory employee than to discipline or fire	.14

<u>Item No.</u>		<u>Weight</u>
23)	Workload leaves little time to help subordinates	.09
27)	Prefer not being a supervisor, but only way to get higher grade	.30
29)	Employees free to bring grievances or appeals to me	.21
34)	Enough disciplinary authority	.22
53)	Trained in how to be a supervisor	.15
60)	Enough backing/authority to do my job	.07
10.	EMPLOYEE SERVICES	
36)	Recreation facilities OK	.16
55)	Medical/health facilities OK	.24
58)	Eating facilities OK	-.09
61)	Transportation facilities OK	.36
63)	Parking facilities OK	.31
11.	MORALE	
59)	Morale in my unit is high	.32
65)	Would recommend this to friends as a place to work	.32

TABLE 4

SHORT INTERPRETATIONS OF THE ELEVEN FACTORS

1. Merit Promotion:
High score denotes dissatisfaction.
2. Training:
Confounded with authority but low score suggests satisfaction in program.
3. Labor-Management Relations:
Low score associated with satisfactory information about roles and treatment.
4. Equal Employment Opportunity:
High score associated with the perception that minority members do not perform as well as others.
5. Classification and Pay:
Load heavily on the question of employees leaving for higher pay elsewhere. High score indicates disagreement with that statement.
6. Position Management:
Driven largely by authority to reassign employees and combine functions. It is confounding, but basically a low score denotes satisfaction with this managerial environment.
7. Job Information and Performance Evaluation:
Loads on communication with subordinates. Low score indicates satisfactory communication is perceived by the supervisors.
8. Communication:
Refers to communication from above. Low score denotes poor communication.
9. Supervision:
Low score expresses satisfaction with their supervisory situation.
10. Facilities:
Transportation and parking seem to be the variable issues. Low score denotes satisfaction.
11. Morale:
Low score denotes high morale.

TABLE 5

DEMOGRAPHIC DISTRIBUTIONS FOR THE SIX CLUSTERS

	<u>Clusters</u>					
	1	2	3	4	5	6
NUMBER OF PEOPLE IN CLUSTER	12	28	10	15	35	6
Military	0	2	4	0	7	0
Civilian (default)	12	26	6	15	28	6
SEX						
Male	4	15	4	7	19	5
Female	7	9	1	5	4	0
YEARS FEDERAL SERVICE						
0-3	0	0	0	0	0	0
4-10	2	3	0	2	2	1
11-20	2	2	1	3	3	1
> 20	7	19	3	7	18	3
EDUCATION						
High School	7	15	4	8	12	3
College	5	9	0	2	7	2
Postgraduate	0	0	0	2	4	0
GENERAL WORK AREA						
Scientific and Eng Professional	0	0	1	1	0	0
Other Professional	1	3	0	2	4	1
Administrative	1	4	1	2	5	2
Technician	2	4	2	3	4	1
Clerical	6	6	1	1	2	1
Trade	1	5	1	3	6	0
GRADE RANGE						
GS 3-5	1	4	0	1	0	0
GS 6-9	7	10	1	6	6	4
GS 10-13	0	5	1	2	6	1
GS 14	0	0	0	0	1	0
Leader	1	3	0	2	0	0
Foreman	2	3	1	2	5	0
General Foreman	0	2	0	0	2	0
Superintendent	0	1	1	0	0	0
WHEN WERE YOU LAST PROMOTED						
Never	0	1	0	0	0	0
0-5	8	16	3	7	16	3
> 5	2	6	1	5	6	2
WHEN DID YOU LAST RECEIVE TRAINING						
Never	0	0	0	1	0	0
0-2	9	24	4	10	22	5
3-5	1	0	0	0	0	0
> 5	0	0	0	1	0	0
MEMBER OF A MINORITY GROUP	2	1	1	0	1	0

T A B L E 6

OFFICE OF CIVILIAN MANPOWER MANAGEMENT SURVEY

SUPERVISORS	Vs. Navy Average ¹	Activity %		Navy % (11/17/71)	
		Yes	No	Yes	No
1. <u>Merit Promotion + 3%</u>					
Satisfied with people referred	+1	54	33	53	32
Good applicants to choose from	+3	47	28	44	28
Candidates in reasonable time	+1	47	38	46	34
Trained in supervisory appraisals	+7	71	22	64	28
2. <u>Training + 2%</u>					
Job related and pays off	+4	80	11	76	12
Can get for employees in reasonable time	+6	61	28	55	30
Difficult to spare employees for off-job training	-5	46	45	40	50
3. <u>Labor-Management Relations +12%</u>					
Personnel office assists in dealing with unions	+13	56	15	43	18
Kept informed of provisions of agreements	+15	69	18	54	21
Feel free to treat union members/non same	+13	87	3	74	3
Trained in Federal program	+6	41	48	35	51
Satisfactory dealings with unions	+14	68	3	54	4
4. <u>EEO + 6%</u>					
Supported by top management and supv's	+1	83	6	82	6
Men and women have same job opportunities	+9	72	13	63	17
Minority members perform as well as others	+6	71	9	65	11
Would mind working for a minority supv	+12	9	79	21	67
Minority members treated fairly	+3	86	4	83	5
5. <u>Classification and Pay + 3%</u>					
Know procedure when PD/JD out of date	+8	81	11	73	17
Participate in annual review of subordinates' PDs/JDs	+3	75	15	72	20
PDs/JDs limit my flexibility in assigning work	+1	22	70	24	69
Know when subordinates' PDs/JDs not current	+6	86	7	80	12
Employees leaving for higher pay is a problem	+5	19	75	22	70
Complete set of PDs/JDs available to me	+5	85	11	80	14
Difference in pay over subordinates' is adequate	+2	56	34	54	34
Pay is enough to attract qualified employees	-5	44	44	49	36
My PD/JD describes what I do	+1	77	15	76	15
6. <u>Position Management + 5%</u>					
Certain functions should be combined	+3	42	43	43	40
Received training in PM	+3	74	17	71	21
Some positions in my unit should do higher priority work	0	31	49	26	49
Aware of PM objectives	+9	69	16	60	22
Could reorganize my unit to be more effective/efficient	+1	35	44	35	43
Enough authority to place/reassign my employees	+2	61	28	59	28

¹Compared to underscored response.

			Activity %		Navy % (11/17/71)	
SUPERVISORS		Vs. Navy Average ¹	Yes	No	Yes	No
	Getting maximum utilization of employees	+10	66	18	56	26
	My skills and abilities well used	+8	75	13	67	20
7.	<u>Job Information, Performance Evaluation + 6%</u>					
	Have some unsatisfactory employees	+7	23	69	30	62
	Periodically discuss performance with subordinates	+5	84	10	79	13
	I see that subordinates know job requirements	+4	94	1	90	1
	Boss lets me know when I do good job	+7	59	25	52	31
	Know what is expected of me	+5	89	3	84	6
8.	<u>Communication + 5%</u>					
	Given "why" on info to me, to answer employee questions	+5	70	21	65	25
	My opinions are considered by management	+6	73	12	67	18
	Usually get info from grapevine first	+3	34	56	38	53
	Regularly attend supervisory staff meetings	+5	60	34	55	37
	Rules and regulations available in writing	+1	77	13	76	12
	Have opportunity to help plan personnel policy	+7	41	43	34	49
	Get most info at same time as employees	+11	35	57	39	46
	Discuss changes with employees in advance	+3	91	1	88	1
9.	<u>Supervision + 4%</u>					
	Used incentive awards system in past year	+2	60	34	58	36
	Not aware of any grievances or appeals in my group not dealt with	-3	68	24	71	20
	Have delegated authority appropriately	+5	94	2	89	6
	Personnel people have more say about my employees than I do	+3	34	54	36	51
	Easier to transfer unsatisfactory employee than discipline or fire him	+8	41	36	50	28
	Workload leaves little time to help subordinates	0	36	58	35	58
	Prefer not being a supervisor, but only way to get higher grade	0	17	75	16	75
	Employees free to bring grievances or appeals to me	-1	95	0	94	1
	Enough disciplinary authority	+9	73	16	64	23
	Trained to be a supervisor	+9	84	9	75	13
	Enough backing/authority to do my job	+9	76	12	67	19
10.	<u>Employee Services + 4%</u>					
	Recreation facilities OK	+1	45	28	44	29
	Medical/health facilities OK	+3	75	11	72	11
	Eating facilities OK	+6	50	37	44	40
	Transportation facilities OK	+4	62	22	58	24
	Parking facilities OK	+5	70	19	65	24
11.	<u>Morale + 5%</u>					
	Morale in my unit is high	+7	64	18	57	25
	Would recommend this place to my friends	+2	70	13	68	16

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